12-1987

Mysis Relicta: Production, Vertical Migration and Life History of the Lake Ontario Population, 1984

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MYSIS RELICTA:

PRODUCTION, VERTICAL MIGRATION AND LIFE HISTORY OF THE LAKE ONTARIO POPULATION, 1984

A Thesis

Presented to the Faculty of the Department of Biological

Sciences

of the State University of New York College at Brockport

in Partial Fulfillment for the Degree of

Master of Science

by

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December 1987

Acknowledgements

I thank Dr. J. Makarewicz for his help and guidance in all phases of this project, in both the field and laboratory. I also thank Dr. J. Haynes and Dr. P. M. Fox for their willingness to help when I needed assistance.

Financial assistance on this research was provided by New York State Sea Grant and the Department of Biological Sciences at SUNY Brockport.

I would also like to thank my friends who helped in various phases of this project: Ted Lewis for his help in the field and his invaluable knowledge of computers, Dawn Deboben for her work on the length-weight analysis of *Mysis relicta* and Greg Teall for his help in the field and the laboratory.

Finally, I thank Marty, my parents and my sister, Jean, for their patience and love during this project.

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ABSTRACT

Mysis relicta was sampled in Lake Ontario biweekly with vertical tows from May through November, 1984. Two sites were studied off Sandy Creek, one station at 35m and the other at 100m. At the 35m station, total abundance values ranged from near zero in late September to $207/m^2$ in mid-August, with a mean abundance of 48 organisms/m^2. Average biomass and production values at the 35m station were 0.08 dry g/m^2 and 0.13 dry g/m^2/7 months, respectively. At the 100m station, total abundance ranged from $110/m^2$ in late September to $860/m^2$ in mid-July, with a mean abundance of $378/m^2$. 0.68 dry g/m^2 was the average biomass and 1.23 dry g/m^2/7 months was the total production at the 100m station. *Mysis relicta* abundance increased from 1971 to 1984 in the offshore and nearshore of Lake Ontario. This may be related to the stocking of salmonines in Lake Ontario or the significant die-off of adult alewives in the winter of 1983-1984.

Samples were also taken to study the vertical migration habits of the *Mysis relicta* population at two sampling sites near Nine Mile Point in Lake Ontario. Amplitude of migration was greater at the 75m station (mean = 27.2m) than at the 35m station (mean = 9.8m).

INTRODUCTION

Changes in a lake's food web are possible with the introduction of exotic or stocking of native fish species. In their classical work, Brooks and Dodson (1965) demonstrated the impact the introduction of blueback herring (*Alosa aestivalis*) had on the zooplankton community of Crystal Lake, Connecticut. Comparisons of the lake's zooplankton population before and after the introduction showed an increase of smaller types and the elimination of the larger species of zooplankton, due primarily to selective grazing of the herring on the large-bodied zooplankton. Similarly, the introduction of an invertebrate predator, *Mysis relicta* to Lake Tahoe caused trophic changes by sharply reducing cladoceran populations, a primary food source of the salmonines (Morgan et. al. 1978).

In the Great Lakes, similar predator induced changes in the composition of the zooplankton community are evident. The decline of the major forage fish, the alewife, (Jude and Tesar 1985, Wells and Hatch 1983) has been linked to the increasing population (7.4 million in 1970 to 16 million in 1980) of stocked salmonines in Lake Michigan (Stewart et al. 1981). The decrease in alewife abundance has reduced size-selective predation on some zooplankton, allowing larger species to return (Scavia et. al. 1986, Wells 1970, Kitchell and Carpenter 1986, Makarewicz 1987). In particular, the return of the large and efficient grazer *Daphnia pulicaria*), not dominant in Lake Michigan prior to 1982 (Evans and Jude 1986), is thought to have led to greater transparency of offshore waters during summer stratification. The long-term ramifications of this manipulation of the food web are still being evaluated.

Similarly in Lake Erie, changes in trophic structure are evident from heavy stocking of a piscivorous fish, the walleye. The recovery of the walleye fishery is as dramatic as the decrease in prey species (alewife, spottail shiner (*Notropis hudsonius*) and emerald shiner (*Notropis atherinoides*)) in the western and central basins of Lake Erie. The appearance and summer dominance of the large and efficient herbivore *Daphnia pulicaria* is attributed to the release from planktivore pressure (Makarewicz 1988).

In Lake Ontario, the stocking of salmonines has increased substantially, from 304,000 individuals in 1968 to over 8 million in 1986 (Daniels and LeTendre 1987). Alewives are the major forage of salmonines (Brandt 1986) and alewife predation on zooplankton is an important link in the food chain leading to sport fish (Brandt 1980, Carpenter et. al. 1985). Up to 1985, no major compositional changes in the Cladocera and Copepoda have been observed with increased fish stocking in Lake Ontario (Johannsson 1987). However, not all species of zooplankton have been evaluated carefully. *Mysis relicta* Loven (Phylum Arthropoda, Class Crustacea, Order Mysidacea, Family Mysidae), a large species of zooplankton seasonally important in the diet of alewife (S. Brandt, personal communication), was last studied intensively using vertical tow nets in Lake Ontario by Carpenter et. al. (1974) prior to the beginning of extensive salmonine stocking.

What changes, if any, have occurred in the Lake Ontario mysid population after more than ten years of increasing salmonine stocking? Adult alewives decreased in abundance due to a large die-off in the winter of 1983-84, causing biomass levels to peak in 1985-86 due to the strong recruitment from the year-classes of 1983 and 1984 (O'Gorman et. al. 1987).

The absence of a large winter die-off during the past several years and a decline in the alewife population in the spring of 1987 suggests that salmonine predation on the alewife population may be the primary factor in this recent decline (Haynes 1987). Although abundance levels increased in the spring and fall of 1987 due to recruitment of yearling alewives (MacNeill 1987), salmonine predation will reach highest levels in Lake Ontario in 1987-88, possibly placing heavy predation pressures on the fluctuating alewife population of Lake Ontario (Haynes 1987). A reduction in the alewife population could potentially lead to an increase in *Mysis relicta* abundance levels, resulting in cascading effects throughout the food web (Carpenter et. al. 1985). In an effort to provide insight into the effects of stocking on trophic levels below the primary forage of the salmonines, an intensive study evaluated the abundance, biomass and production of the *Mysis relicta* population of Lake Ontario in 1984, a year of lower alewife abundance.

MATERIALS AND METHODS

Two locations on Lake Ontario, one off Sandy Creek near Hamlin Beach State Park (43° 21' 44" latitude and 77° 56' 39" longitude) and the other at Nine Mile Point near Oswego, N.Y. (43° 31' 30" latitude and 76° 22' 07" longitude) (Fig. 1) were sampled for Mysis relicta. Vertical migration studies were conducted at Nine Mile Point, while Sandy Creek time trend data were collected on abundance, biomass and secondary production. Two depths were sampled at each site; a 35m station (3km offshore) and a 100m station (9km offshore) at Sandy Creek and a 35m station (2km offshore) and a 75m station (5km offshore) at Nine Mile Point. Sampling sites were located with a Loran unit and a depth finder.

The Sandy Creek site was sampled biweekly within a three hour period (2300 to 0200) after total darkness from May 17, 1984 to November 26, 1984, weather permitting. Replicate double BONGO tows (n=4) (571 um mesh net, 50 cm diameter), equipped with flow meters, were hauled vertically from 2m above the bottom to the surface to sample for Mysis relicta. A vertical single BONGO tow (80 um mesh net, 50 cm diameter) was hauled from 2m above the bottom to the surface to sample the zooplankton population. Benthic sled tows (571 um mesh net, 1 m^2 mouth) were done at both stations to sample the benthic population of mysids. Depth of sampling was determined with a meter wheel and a fathometer.

The Nine Mile Point site was sampled during three seasons in 1984; spring (May 31), summer (June 26 and August 21), and fall (October 23). Each sampling trip covered, at a minimum, a 24-hour period, with sampling being repeated every 4 hours. The double BONGO nets were towed horizontally at 5m, 15m, and 25m at the 35m station, and at 5m, 25m and 50m at the 75m station. Towing depth was calculated by the "wire length-wire angle" conversions as used by Folt, Rybock and Goldman (1982).

The contents of the nets were washed down into a sampling bucket, transferred to bottles and preserved with 10% formalin. All _M_. _relicta_ were individually measured (body length) (Morgan and Beeton 1978). Eggs or embryos were also removed from female mysids, counted and measured. Sex of adults was determined by the appearance of the fourth pleopod (Pennak 1978).

Forty _M_. _relicta_ were measured, dried in a drying oven at 60°C and individually weighed after cooling for one hour in a dessicator (Makarewicz and Likens 1979). Smaller organisms (_M_. _relicta_ < 6.5 mm) were placed in groups of ten to be dried and weighed. A length-weight relationship for _M_. _relicta_ was developed by least-squares linear regression analysis (Fig. 2).

Cohorts within the population were identified with histograms of length versus number of individuals (Fig. 3). With the availability of cohort data, the "growth-increment summation" technique (Downing and Rigler 1984) was used to calculate production.

Temperature profiles were obtained with a bathythermograph. Dusk and dawn light readings were taken only at the Nine Mile Point site with a G.M. Manufacturing Company Model submarine photometer. Readings were taken every meter from the surface to approximately 10m of depth, then every 2m thereafter until light could not be detected.

RESULTS

Biomass and Production

The *Mysis relicta* population of the nearshore region (35m) was composed of four cohorts (Fig. 4). Cohort one was observed only on June 4, 1984 and had an average length of 1.95cm. Cohorts two and three had the largest increase in abundance during the early summer (Fig. 5) and contributed 94% of the total production of *Mysis relicta* at 35m (Table 1). In mid-August, cohort four appeared and was the only cohort observed on the final sampling date, November 26, 1984 (Fig. 4). Cohort four had the largest increase in size during the sampling period (Fig. 4) and contributed 6% to the total production of *Mysis relicta* at 35m (Table 1).

At the offshore station (100m), five cohorts of *Mysis relicta* were observed (Fig. 6). The initial length of cohort one was 1.91cm. The maximum length of cohort one (Fig. 5), before the cohort disappeared in mid-August, was 2.10cm. This cohort, which represented the oldest members of the population, was 96% female. Of the five cohorts observed, cohorts two and three had the largest increases in biomass over the sampling period (Fig. 7), and thus contributed the highest production (92%) to the mysid population between May and November, 1984 (Table 1). Cohort four represented 7% of the total production at 100m (Table 1). Cohort five appeared in October and was represented by eggs and embryos only (Fig. 6).

The total cohort abundance at the 35m station ranged from near zero in late September to 207/m^2 in mid-August (Fig. 8). At the 100m station, the population density was lowest in late September at 110/m^2 and peaked in mid-July at 860/m^2 (Fig. 8). Mean density at the 35m station was 48 individuals/m^2, while average biomass and production values were 0.08 dry

g/m^2 and 0.13 dry $g/m^2/7$ months, respectively. At 100 meters, the average density was $378/m^2$, mean biomass was 0.68 dry g/m^2 and total production for the study period was 1.23 dry $g/m^2/7$ months (Table 4). At both 35m and 100m, the individual growth and population growth of cohorts two and three was reflected in the large increases in biomass from June through August. The biomass values at 100m remained high into November due to the growth of cohort four and the addition of cohort five (Fig. 6). Mean total biomass values were 2.38 mg/m^3 at the 35m station and 6.81 mg/m^3 at the 100m station.

Because the vertical tows came only within 2m of the bottom, epibenthic sled tows were taken along with the double bongo vertical hauls at both the 35m and 100m stations at Sandy Creek. The benthic sled tows were used to estimate mysid abundance in an area not sampled by the vertical tow and to demonstrate that our vertical night hauls were quantitative samples representing the entire water column. If sled abundances are added to vertical tow abundances at each station, abundance changes little (from $1.37/m^3$ to $1.44/m^3$ at 35m and from $3.78/m^3$ to $3.82/m^3$ at 100m). Therefore, when *M. relicta* is sampled with vertical hauls at night, the entire population is adequately represented.

Gravid females were found twice, in the spring and the fall samples. Clutches were larger in the fall by approximately 1/3. Although seasonal variations did occur, the male:female ratio was 1:1.5 for the entire sampling period (Fig. 9).

Vertical Migration

A migration of *M. relicta*, vertically within the water column was observed at both Nine Mile Point stations. Amplitude of migration was greater at the 75m station (mean = 27.2m) than at the 35m station (mean = 9.8m). Seasonally, the amplitude of migration was greater during thermal stratification (mean = 36.6m at 75m, mean =10.8m at 35m) than at fall turnover (8.4m at 75m, 6.7m at 35m) at both stations (Fig. 10). The upward movement of the average individual never exceeded 20m at the 35m station and did not surpass 30m at the 75m station (Fig. 10). Quartile curves (Pennak 1943) indicate very rapid ascents and descents of the *M. relicta* populations at sunset and sunrise (Fig. 11). The mean rate of ascent at 35m was 1.6m/hour and the average rate of descent was 3.1m/hour. At 100m, the average rates of ascent and descent were 6.8m/hour and 5.5m/hour, respectively. Temperature gradients of 1.0°C/m (Fig. 12) did not appear to create a barrier to vertical migration. The maximum temperature into which the 25% quartile of mysids migrated was 14°C. The mean temperature range for the depth of the average individual was between 4-10°C at the 35m station and 4-6°C at the 75m location.

DISCUSSION

Factors Effecting Abundance and Biomass of *Mysis relicta*

Trophic interactions may regulate the populations in an area and the alteration of consumer populations has been found to effect all levels in the trophic structure of a community (Carpenter et. al. 1985). In Lake Ontario, the stocking of sport fish, such as piscivorous salmonines, may have far-reaching effects on the food web at levels below their primary food resources. Alewives (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) are the primary prey for the salmonines (Brandt 1986) and these fish in turn feed on zooplankton and fish larvae.

Predation

Recent unpublished work (Iancu 1987) demonstrates that alewives possess two feeding strategies in Lake Ontario. Iancu's study, done in conjunction with ours, found that 12% of the alewife population begins to feed heavily on *Mysis* in early summer (Fig. 13, Table 2), while the rest of the population continued to feed on Cladocera and Copepoda. In August and October, *Mysis* comprised 46.0% and 48.5% of the alewife feeding strategy one diet, which represented 39.5% and 66.5% of the total alewife population, respectively. This switching behavior of a portion of the alewife population may be related to availability of either large sized prey such as *Mysis* and/or abundant cohorts of *Mysis*. In June, individuals of cohort 1 are large but few in number (Figs. 6 and 7). Cohorts 3 and 4 are abundant but small in size. Only individuals of cohort 2 are large but relatively low in number during June. By July, cohort 2 and 3 are abundant and growing rapidly, providing a relatively large energy source to alewives.

In August when alewives were feeding on *Mysis*, a large drop in the mysid population was observed (Fig. 8) primarily in cohort 3 but also in cohort 2 (Fig. 7). The mysid population at 100m peaks in mid-July at $860/m^2$, sharply drops off to $110/m^2$ by September and stabilizes at low levels in October. The 35m station shows similar trends, peaking at $207/m^2$ in mid-August and dropping to near zero in late September (Fig. 8). Seasonally, alewifes appear to effect *Mysis* abundance.

Temperature and Horizontal Movement

The decrease in mysid abundance (Fig. 8) observed at the 35m station in mid-July occurs when the water column temperature reaches 16^oC (summer range=15^o-22^o) (Fig. 14). *Mysis relicta* cannot tolerate temperatures $>10^oC$ in the hypolimnion and $>14^oC$ in the epilimnion for extended periods of time (Smith 1970). Presumably, mysids move to the cooler water at greater depths (Fig. 15) (Morgan et. al. 1978). Abundance of mysids in the offshore region of Lake Ontario does peak when abundance at the nearshore is depressed by high temperatures (Fig. 8). Further evidence that temperature is restricting mysid abundance and distribution at the nearshore station was provided during an upwelling event. In mid-August, 4^oC water upwelled into the nearshore to approximately 14m (Fig. 14). Abundance of *M. relicta* increased dramatically during this event (Fig. 8). Over the study period, the higher nearshore temperatures of the entire water column were reflected in a lower mysid abundance at 35m (mean = $48/m^2$) as compared to the 100m station (mean = $378/m^2$) which possessed an extensive cold hypolimnion throughout summer stratification (Fig. 16).

Historical Trends in Abundance

Carpenter et. al. (1974) sampled in April, August and November 1971 at 33 stations in Lake Ontario, using vertical hauls with nets similar in mesh size to ours (Table 3). Although day and night samples were taken by Carpenter et. al. (1974) and grouped together, no variations in abundance were observed between them. This finding is important because much concern has risen over daylight samples underestimating *Mysis* abundance (Grossnickle and Morgan 1979). The success of the daylight quantitative samples was attributed to the design of the net which allowed it to rest on its side on the bottom of the lake and sample the benthic *M. relicta* population along with those individuals present in the water column. Abundance in 1971 was estimated at $0.14/m^3$ at the 25-50m stations and 1.15 *Mysis relicta*/m^3 and $1.67/m^3$, at the 75-100m and the 100-125m stations, respectively. Even when abundances are calculated using only the time periods during which Carpenter sampled, values of 1.67 *Mysis relicta*/m^3 at 35m and $4.04/m^3$ at 100m were found (Table 3). Abundances calculated for this study are 1.37 mysids/m^3 at 35m and 3.78 mysids/m^3 at 100m. Due to the range in depths Carpenter reported for his sampling sites, we also calculated his abundance values on a number/m^2 basis, using both the minimum depth and maximum depth given for each station. The values for Carpenter's 25-50m station range from 3.5 *M. relicta*/m^2 to $7.0/m^2$ (this study - 48.0 *M. relicta*/m^2 at 35m) and at the 100-125m station, the 1971 abundances range from $167/m^2$ to $209/m^2$ (this study - 378 *M. relicta*/m^2 at 100m) (Table 3). The 1984 abundance values were $48/m^2$ at 35m and 378 mysids/m^2 at 100m. The 1971 abundances are markedly lower than those observed in 1984.

Comparisons of these two data sets indicate an increase in the mysid population between 1971 and 1984. In the alewife population, the adults are responsible for most of the predation on mysids (Brandt 1980). Adult alewife abundance decreased by more than 50% in 1984 from previous years (O'Gorman et. al. 1987) and it appears that when alewife abundance decreases mysid abundance increases in response to the lowered predation pressures placed on it. Although unlikely, this increase in *Mysis* abundance could be a reflection of a bottom-up effect, such as increasing levels of phosphorus. However, Dobson (1984) found that Lake Ontario's phosphorus levels peaked in 1973 and have declined since then.

Johannsson's et. al. (1985) 1983 sampling for Lake Ontario *Mysis* resulted in extremely low mysid abundances (Table 4). Abundance values of 0.13 mysids/m^3 at 35m and 0.16/m^3 at a 105m station were observed. These values are apparently an underestimation of the *M. relicta* population because sampling was done exclusively with a Ponar grab sampler. This type of sampler would underestimate the population due to the possibility of some mysids being in the water column, particularly the juveniles (Beeton 1960) and because of the inefficiency of this type of sampler on some substrates (Downing and Rigler 1984).

Secondary Production

The identification of cohort structures allowed the use of the "growth-increment summation" method of calculating production. This method requires a complete population history and assumes that all mortalities in the mysid population occur at the lengths which divide each size class and that all organisms in a size class grow at equal rates (Downing and Rigler 1984). Production values for 1984 in Lake Ontario were 0.13 g/m^2/7 months and 1.23 $g/m^2/7$ months for the 35m and 100m stations, respectively. Cohort one, seen only during the first five sampling dates, and cohort five, found exclusively during the last four samples, accounted for none of the production at 35m and < 2% of the production at 100m (Table 1). Cohorts two and three contributed the largest percentage of production to the *M. relicta* population, 94% and 92% at 35m and 100m, respectively (Table 1). A large portion of the secondary production of cohorts two and three can be attributed to their rapid growth in the fall (Fig. 6) due to greater food resources and cooler temperatures.

The difficulty of identifying cohorts prompted Sell (1982), who reviewed data from five Great Lakes mysid studies, to use the size-frequency method of calculating production. This method does not require cohort identification (Hynes 1980), but by using Menzie's (1980) modification of the Hynes method, fairly accurate production values can be calculated. Comparisons of Sell's (1982) production and biomass values with those of this study's show fairly large variations between the data sets, although production to biomass ratios for the studies show very little variability (Table 4). P:B ratios have been shown to be similar for a species in various environs (Makarewicz and Likens 1979).

When comparing the production values found in this study to those of Lake Michigan, many variables must be considered. Table 4 shows studies done on Lake Michigan from 1954 (Beeton 1960) to 1976 (Grossnickle and Morgan 1979, Morgan and Beeton 1978). The two studies which sampled during the day (Reynolds and DeGraeve 1972, Morgan and Beeton 1978) show very low production levels, as would be expected. Beeton's (1960) 1954 study estimated Lake Michigan's mysid production at 2.5 dry $g/m^2/year$, while Grossnickle and Morgan (1979) estimated production at 3.2 dry $g/m^2/year$ for

1975-1976. Both values for Lake Michigan are higher than those found for Lake Ontario in 1984 (1.23 dry $g/m^2/7$ months at 100m). Perhaps the 1975-1976 higher production values (Grossnickle and Morgan 1979) reflect the late 1960's (Wells 1970) and early 1970's (Stewart et. al. 1981) decline in the alewife population.

Relative Importance of *Mysis relicta* in the Zooplankton Population

Zooplankton tows taken in conjunction with each mysid sample allowed comparisons of the relative importance of each zooplankton group (Tables 5a and 5b). On an abundance basis at both stations, *Mysis relicta* appears to be insignificant representing <0.0% of the total zooplankton community. When biomass of each zooplankton group is considered the importance of *M. relicta* increases. At 100m, the mysids contributed 5.8% of the total zooplankton biomass ranking higher than the rotifers and adult calanoid copepods. *Mysis relicta* accounted for 1.0% of the total biomass at the 35m station.

Male:Female Ratios

Changes in female to male ratios of mysid populations are dependent on the differential mortality of the sexes (Blaxter et. al. 1980). During the summer in Lake Ontario, there is a higher percentage of females present due to the die-off of males after copulation in May (Fig. 9). The steady increase in the percentage of males in the population into autumn reflects the mortality of the females after the fall hatch. The mean number of females from the beginning of the sampling season until the fall hatch was 70.0 individuals in contrast to 38.8 males. During the hatch of cohort five from October through November (Fig. 6), the mean number of females drops to 45.5 while the average number of males for the final four sampling dates increases to 55.8.

For the entire sampling period, male : female ratios (Fig. 9) were approximately 1:1.5, which falls into the range observed in other lakes. For instance, Hakala (1978) reports a 1:1 ratio for Lake Paajarvi, Finland for data collected year-round. Male : female ratios of 1:1 and 1:2 were reported by Morgan (1980) for samples taken in Lake Tahoe and Emerald Bay.

Reproduction

McWilliams (1970) reports four breeding seasons for *Mysis relicta* in Lake Michigan; mid-spring, late summer, mid-fall and late winter. In Lake Ontario, one cohort of *Mysis relicta* was produced just before sampling began in mid-May and a second cohort appears in early October (Figs. 6 and 7). With a gestation time of five months (Berrill 1969) for *Mysis relicta*, breeding would have occurred in January and May. A summer brood was not observed. Because sampling was limited to the spring through fall period, the existence of a winter hatch was not confirmed. However, back calculation from the cohort growth curves suggests that winter breeding does not occur in Lake Ontario.

Brood Size

Brood size decreased as embryo development progressed (Table 6). Berrill (1969) described the various stages of embryonic development in *Mysis relicta*, stage one being the earliest developmental stage of the embryo with no activity present, and the third stage occuring when the embryo is about to undergo its first molt. In this study, the average brood size at stage one was 29.6 embryos/female and 18.5 embryos/female at stage three, representing a significant loss ($P<0.10$) of 37.5% between stages one and three (Table 6). In Emerald Bay, Morgan (1980) found a decline in brood size of 26% over the entire brooding period.

VERTICAL MIGRATION

Vertical migration provides a population with the ability to feed in a much larger area, thereby allowing a body of water to support a greater population. By migrating through the water column at night, predator avoidance (Zaret and Suffern 1976, Enright 1977, Janssen and Brandt 1980) is possible due to the strong use of visual stimuli employed by certain fish. During the day, the cooler hypolimnetic environment enables the mysids to have lower metabolic rates (Beeton and Bowers 1982). Reproductive capabilities are thus increased in this situation, with more energy available due to lower maintenance costs.

The extent of vertical migration has been found to be limited by density and temperature gradients (Calaban and Makarewicz 1982). Temperature tolerances of *Mysis relicta* allow it to feed in waters up to $11^{\circ}C$ (Pennak 1943), although survival at temperatures of $22^{\circ}C$ has been noted (Reynolds and DeGraeve 1972). This study found that the maximum temperature the mysids migrated into was $14^{\circ}C$, although the depth of the average individual graphs indicate that the population favored 4-$10^{\circ}C$ at 35m and 4-$6^{\circ}C$ at 100m (Figs. 10 and 12).

Lasenby and Langford (1972) and Beeton and Bowers (1982) found that from early summer to late fall, there is a progressively earlier ascent and later descent of the mysid population due to the change in daylight hours. This also occured in the Lake Ontario *M. relicta* population (Fig. 10). At the 35m station, the June ascent and descent were at 8:00 PM and 4:00 AM respectively, while in October, the mysids began migrating upwards at 3:00 PM and did not finish their descent until 6:30 AM. Because of the greater depth and therefore the less obvious light changes near the bottom, these seasonal time changes were not as pronounced at the 100m station.

Mysis relicta has been found to aggregate in the metalimnion at night, although they may first migrate up through it and then descend to feed in or just below it (Beeton 1960). Figure 10 illustrates the extent of the migration of the average individual, the shallowest point reached being 22m at the 35m station and 35m at the 75m station. The temperature, light and food at this level in the water column all combine to provide the optimum conditions for the mysids and it is at this depth where they will stay to feed until the morning descent.

Beeton (1960) reported rates of ascent at a 38m station in Lake Michigan to be 30m/hour in July and August and 48m/hour in October. Rates of descent were calculated to be 24m/hour in June. This study reports average rates of ascent and descent to be 1.6m/hour and 3.1m/hour at 35m and 6.8m/hour and 5.5m/hour at 100m, respectively. The longer time between samples in this study may have underestimated the rates of movement.

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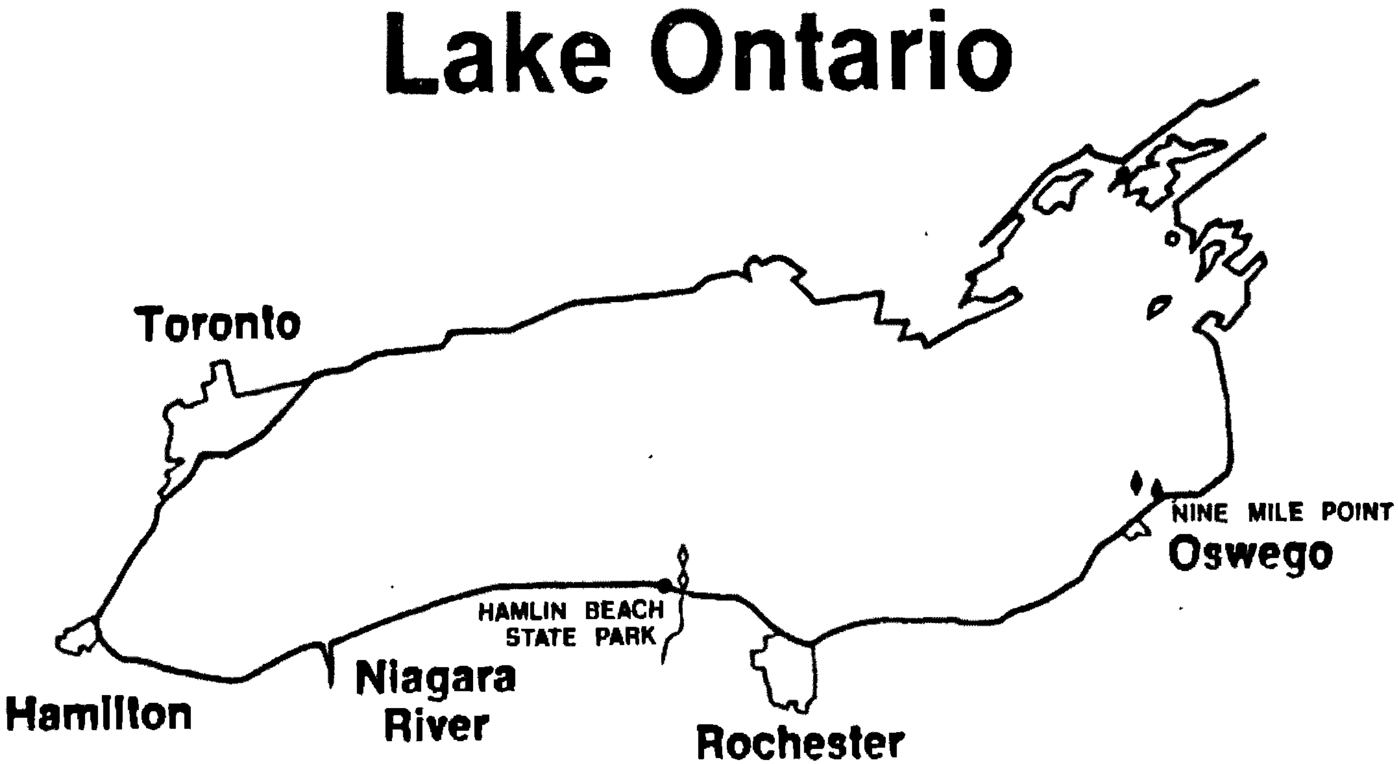

Figure 1 Lake Ontario sampling sites for *Mysis relicta*. 1984.

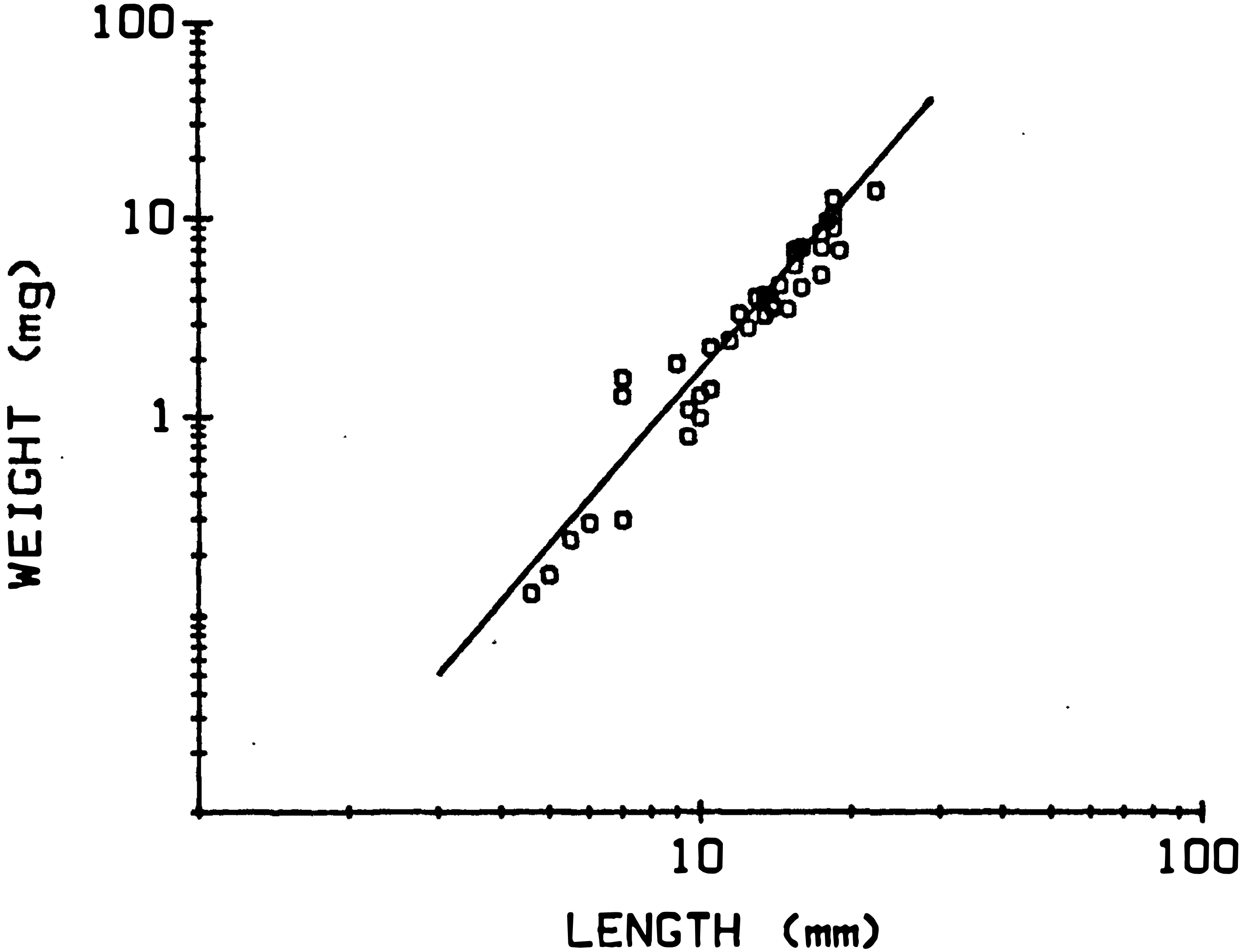

Figure 2 Length-dry weight relationship for the Mysis relicta population in Lake Ontario. Values are plotted on logrithmic axes. (Log mg = -2.68 + 2.86 Log mm, r^2 = 0.96)

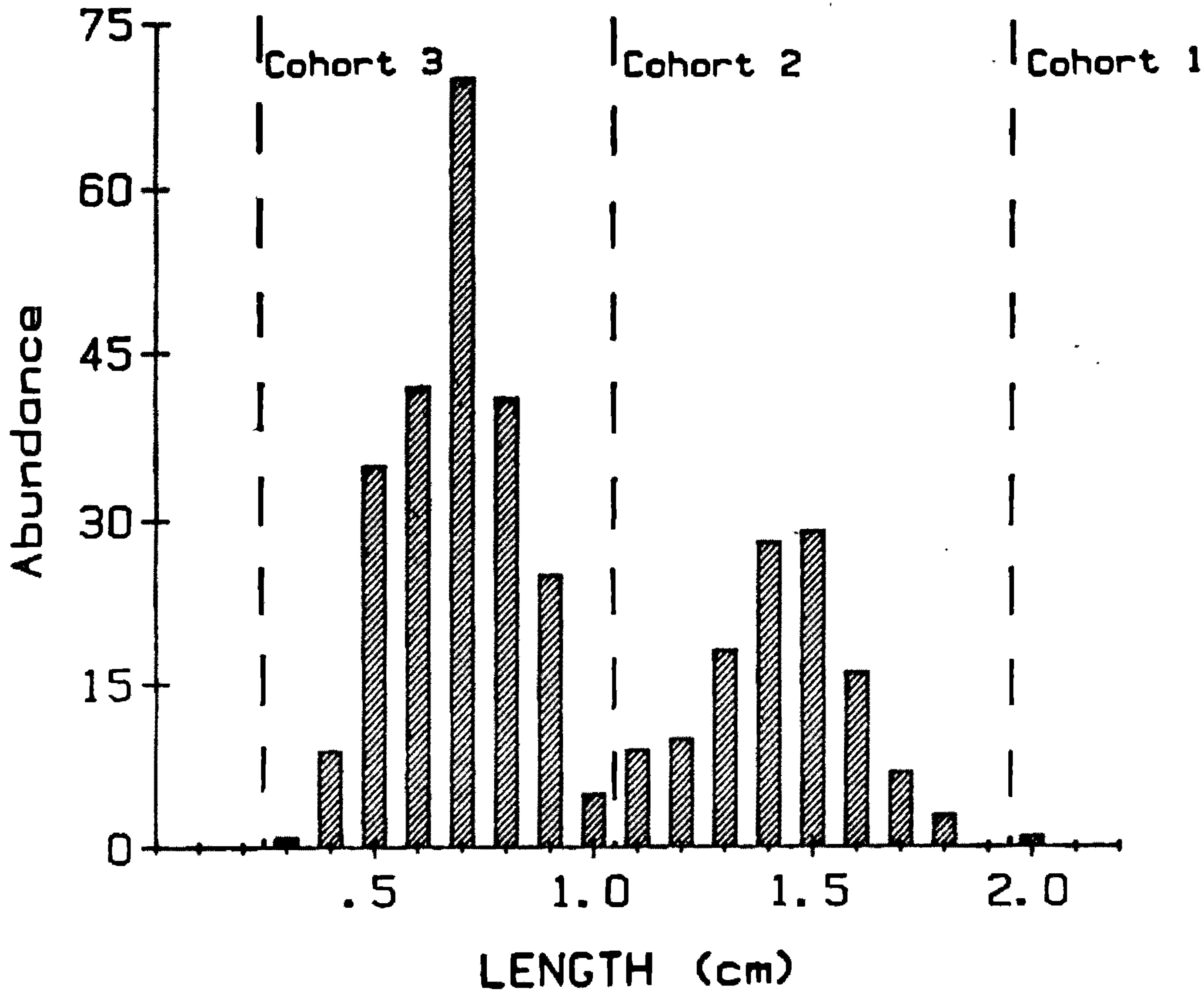

Figure 3. Example of histogram used to determine the cohort structure of the *Mysis relicta* population, 100m station in Lake Ontario off Sandy Creek, July 5, 1984.

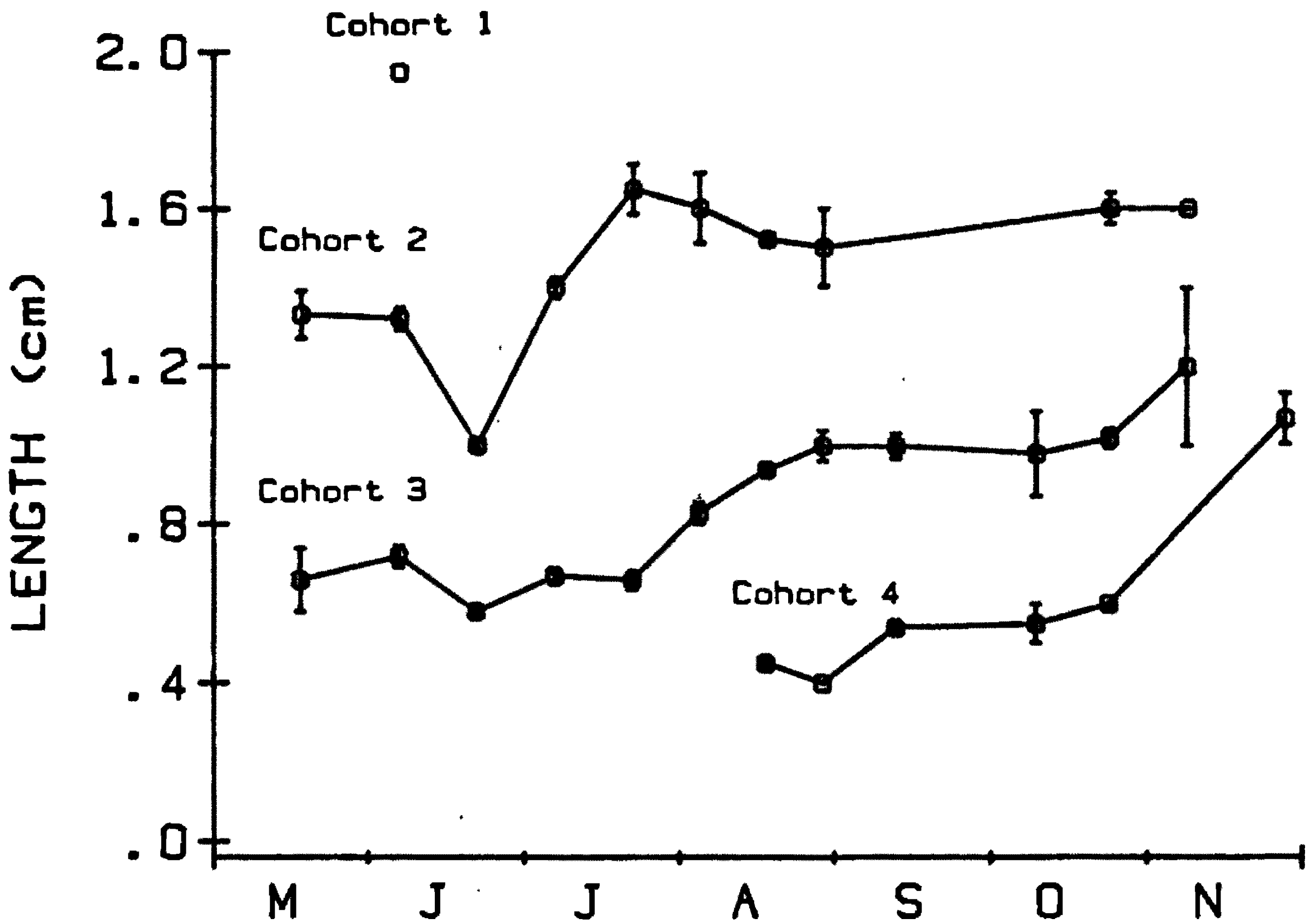

Figure 4 *Mysis relicta* cohort growth at the 35m station, Lake Ontario off Sandy Creek, 1984. Values are the mean ± the standard error.

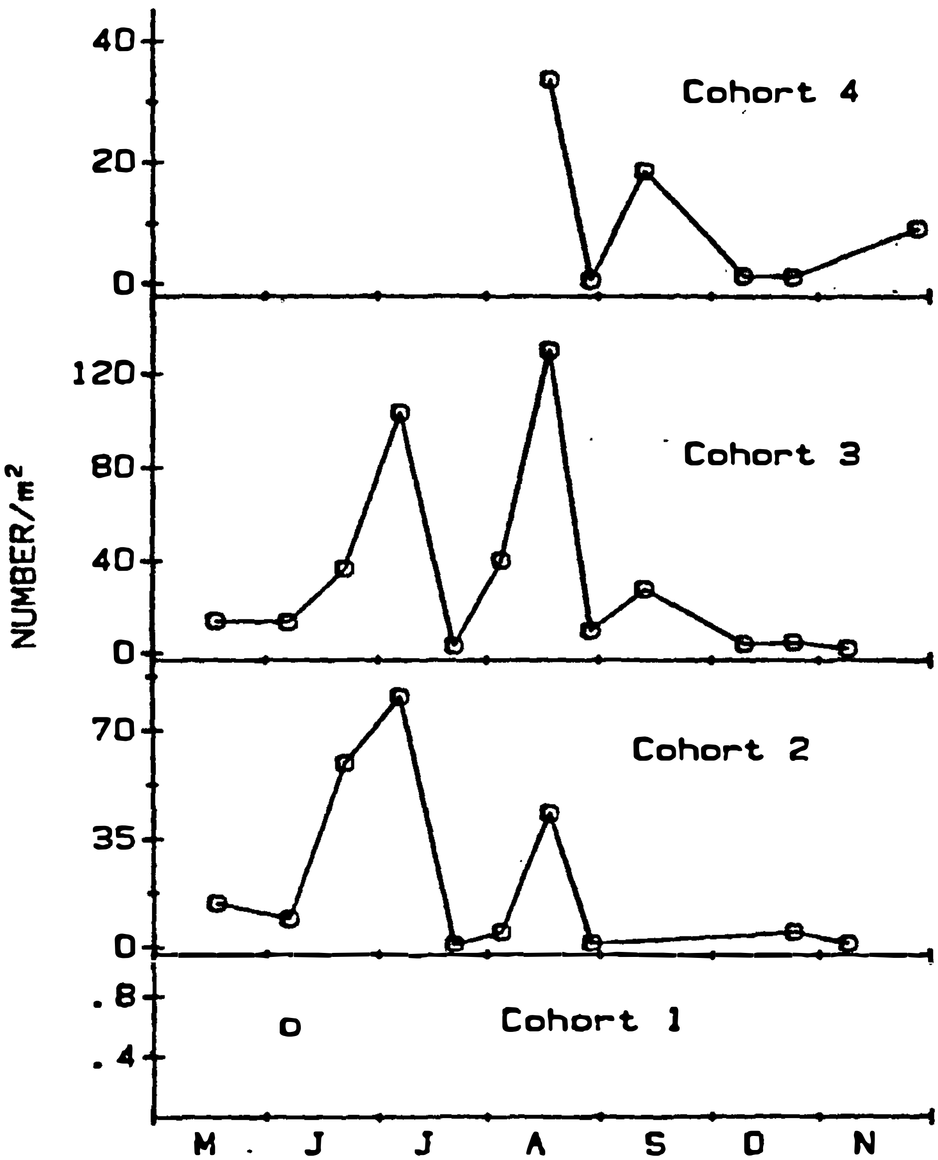

Figure 5 Cohort abundances for *Mysis relicta* at the 35m station, Lake Ontario off Sandy Creek, 1984.

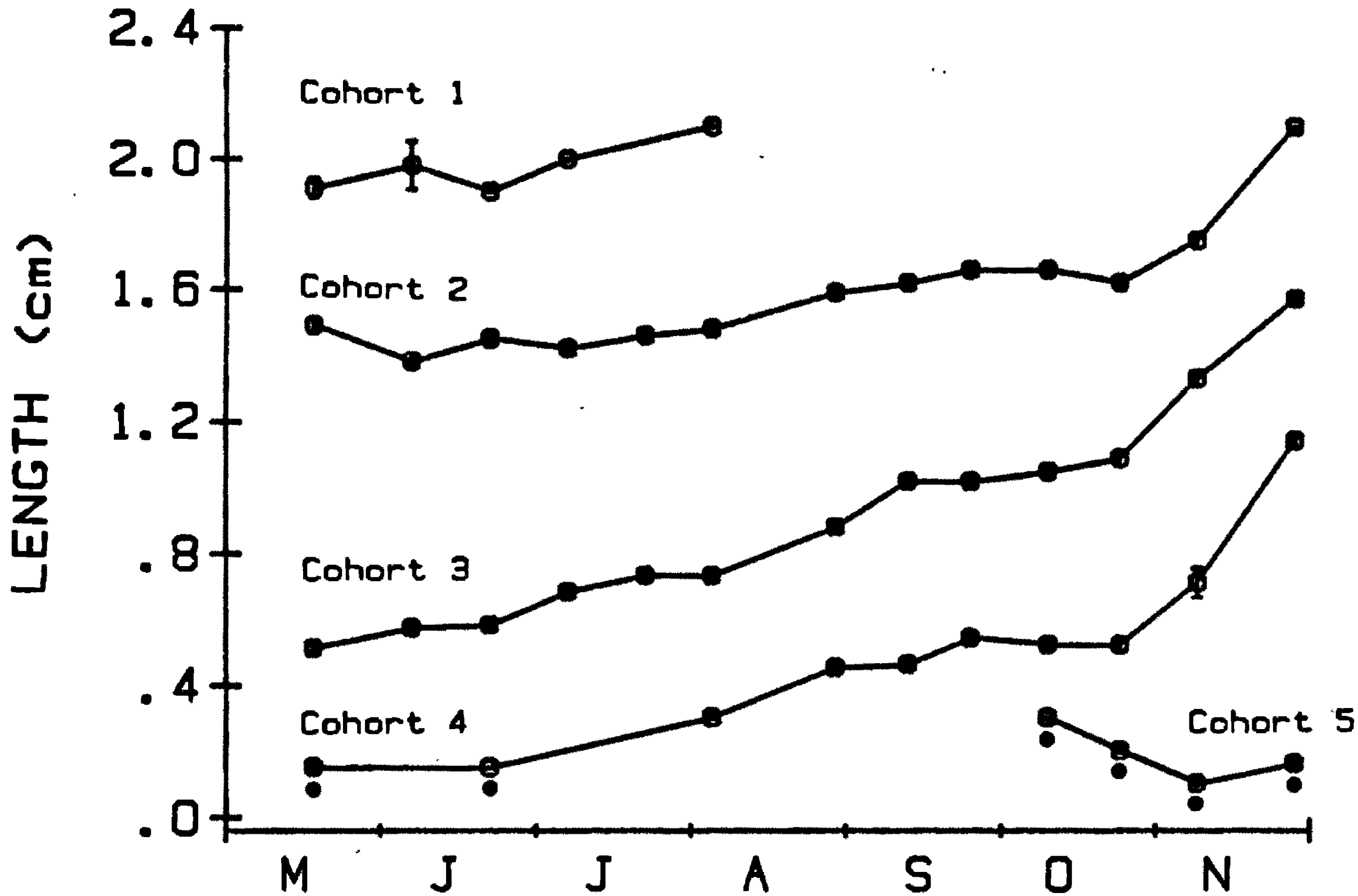

Figure 6 *Mysis relicta* cohort growth at the 100m station, Lake Ontario off Sandy Creek, 1984. Values are the mean ± the standard error. Solid circles represent embryos.

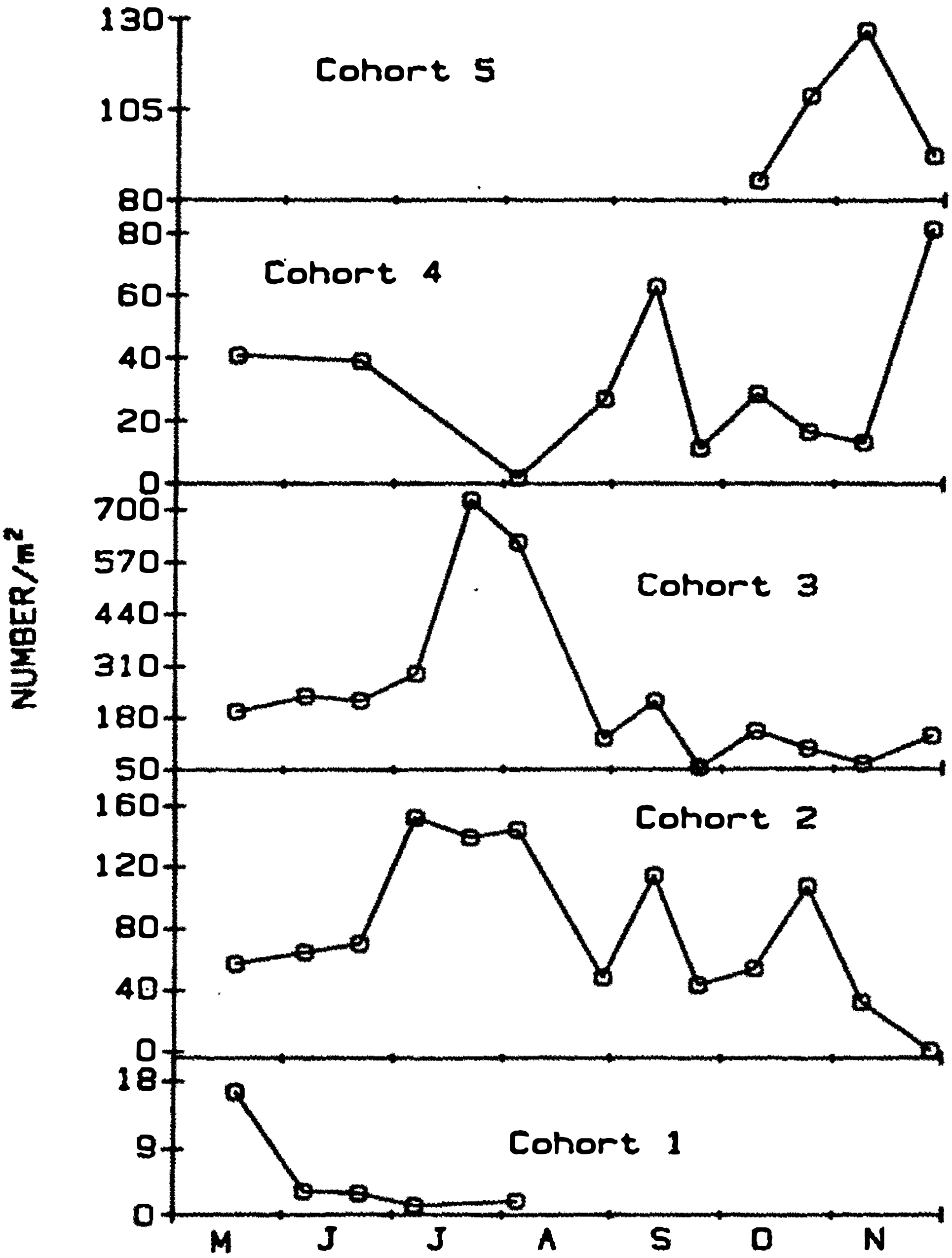

Figure 7 Cohort abundances for *Mysis relicta* at the 100m station, Lake Ontario off Sandy Creek, 1984.

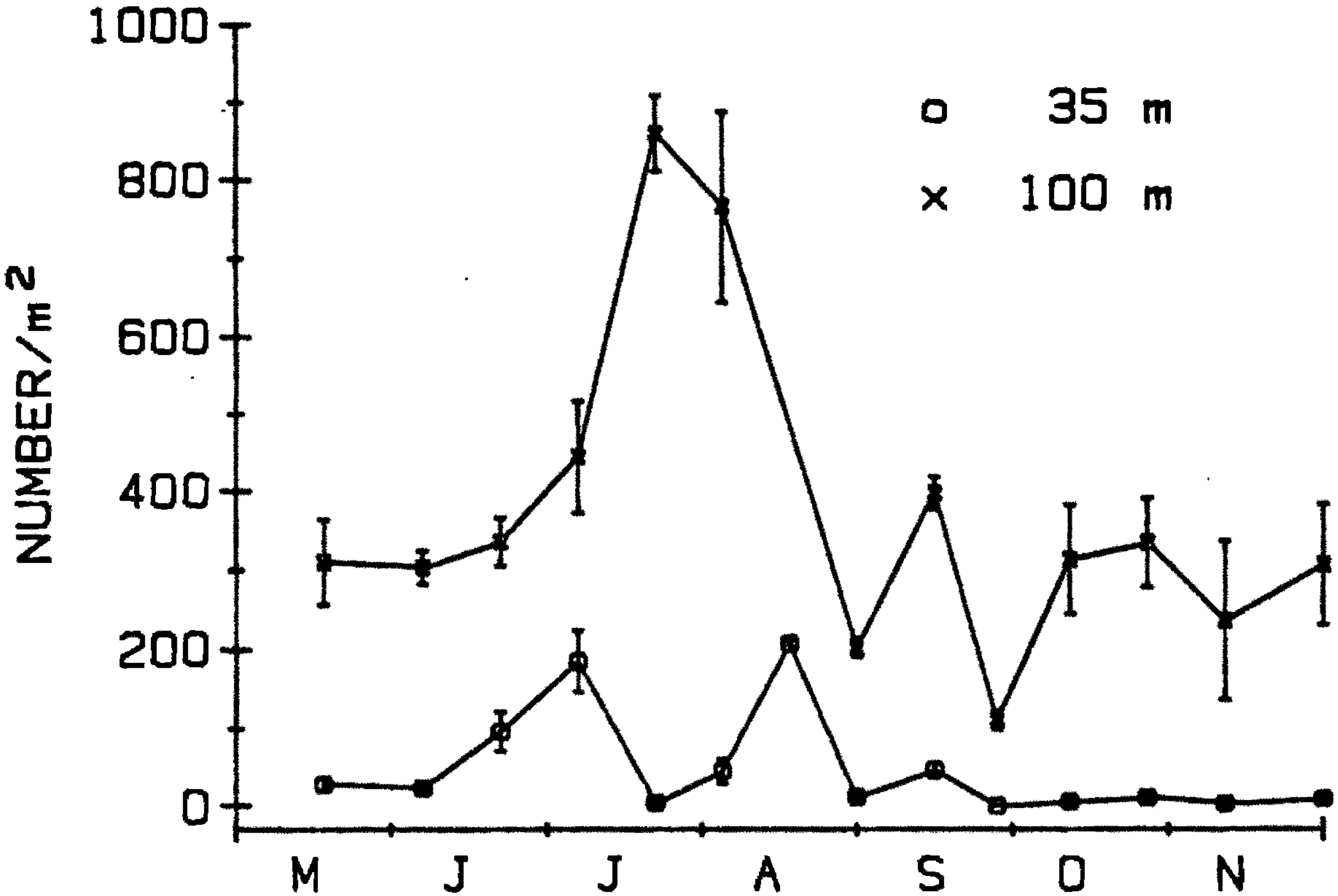

Figure 8   Total abundance for the *Mysis relicta* population, Lake Ontario off Sandy Creek, 1984.

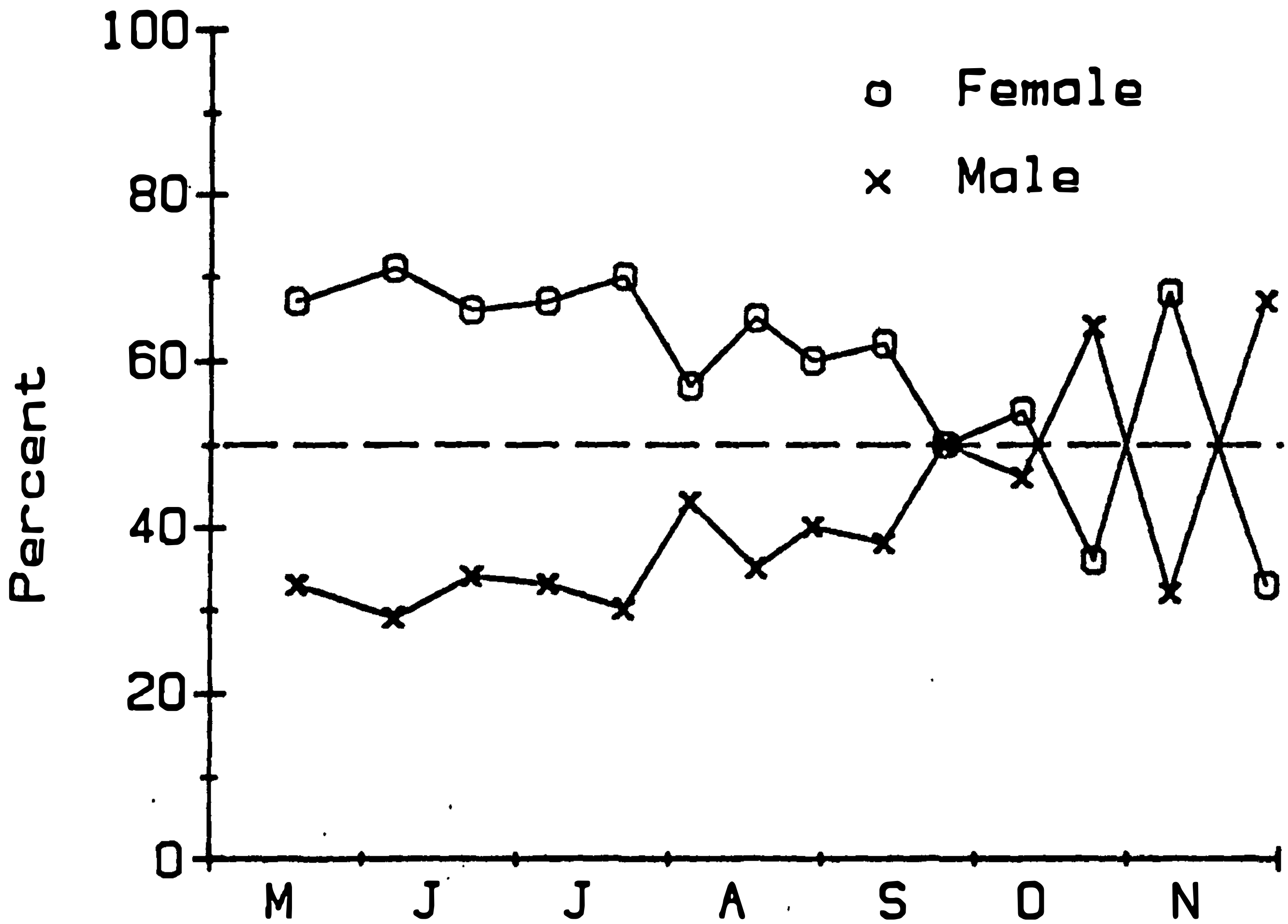

Figure 9 Percent male and female adult <u>Mysis relicta</u>, Lake Ontario off Sandy Creek, 1984.

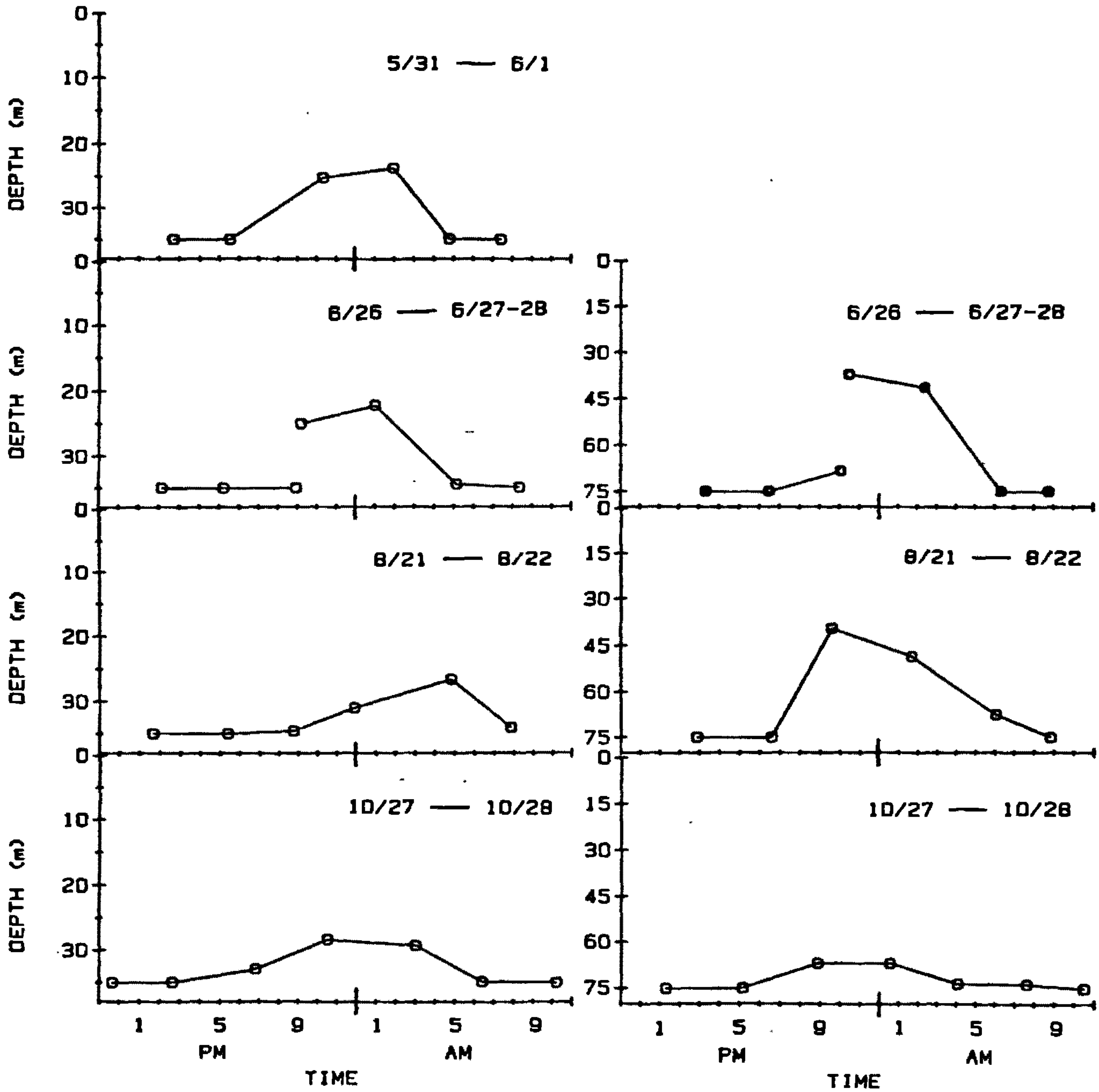

Figure 10 Depth of the average individual of *Mysis relicta* at the 35m and 75m stations, Lake Ontario off Nine Mile Point, 1984 .

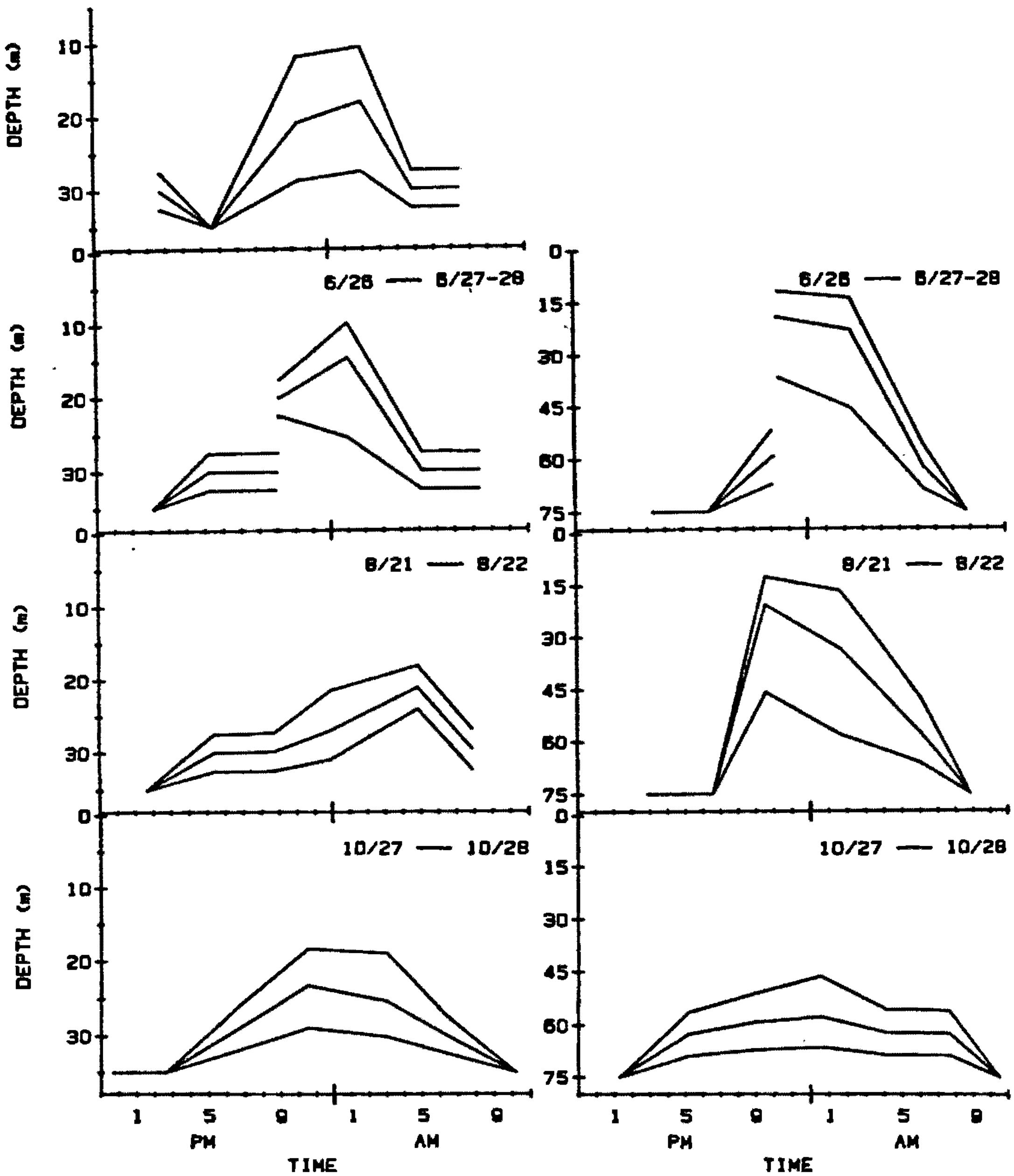

Figure 11. Vertical migration of Mysis relicta expressed as quartile curves at the 35m and 75m stations, Lake Ontario off Nine Mile Point, 1984. The top line represents the depth at which 75% of the population is found at or below, the middle line represents the 50% quartile and the bottom line is the 25% quartile.

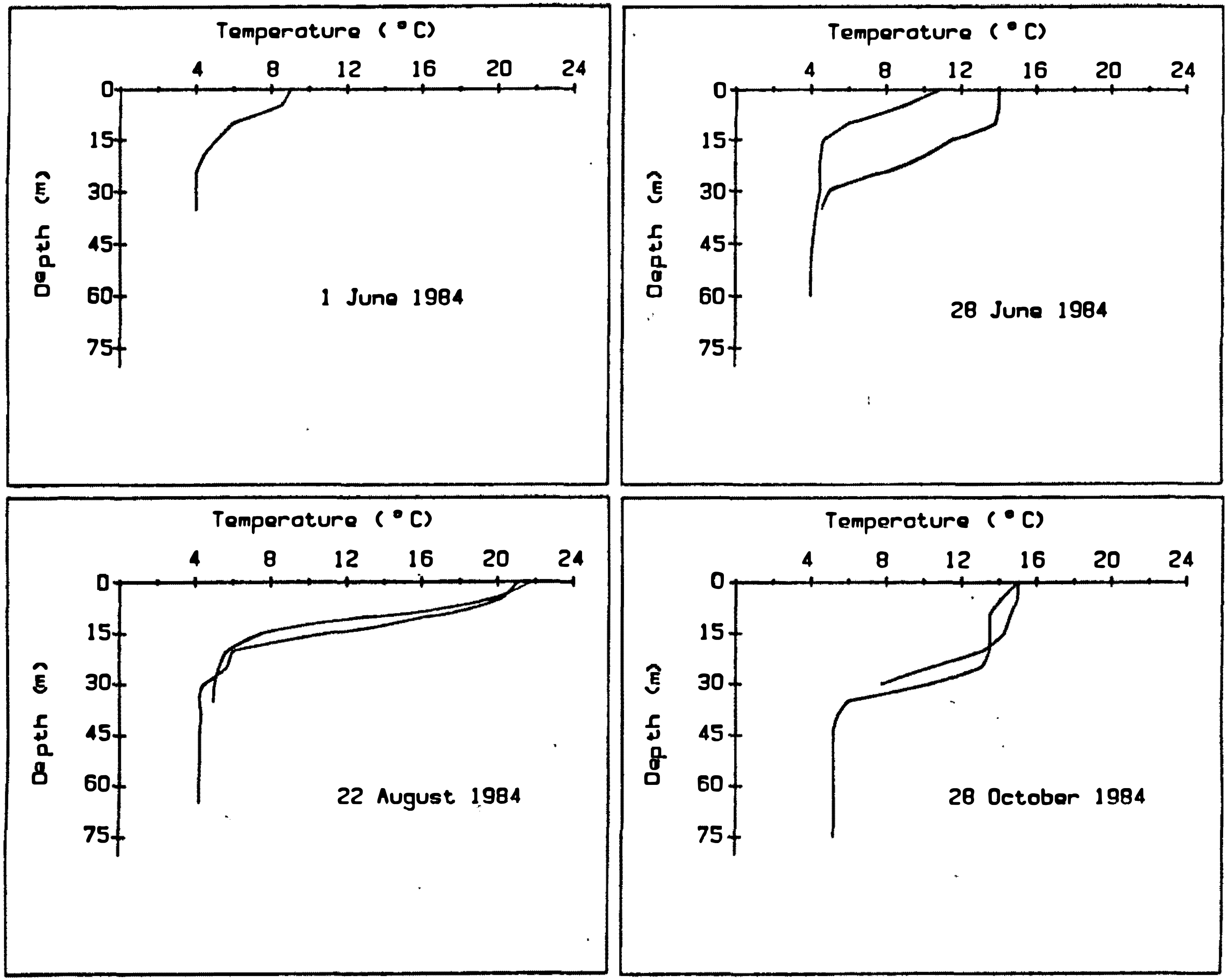

Figure 12. Temperature profiles of the 35m and 75m stations, Lake Ontario off Nine Mile Point, 1984.

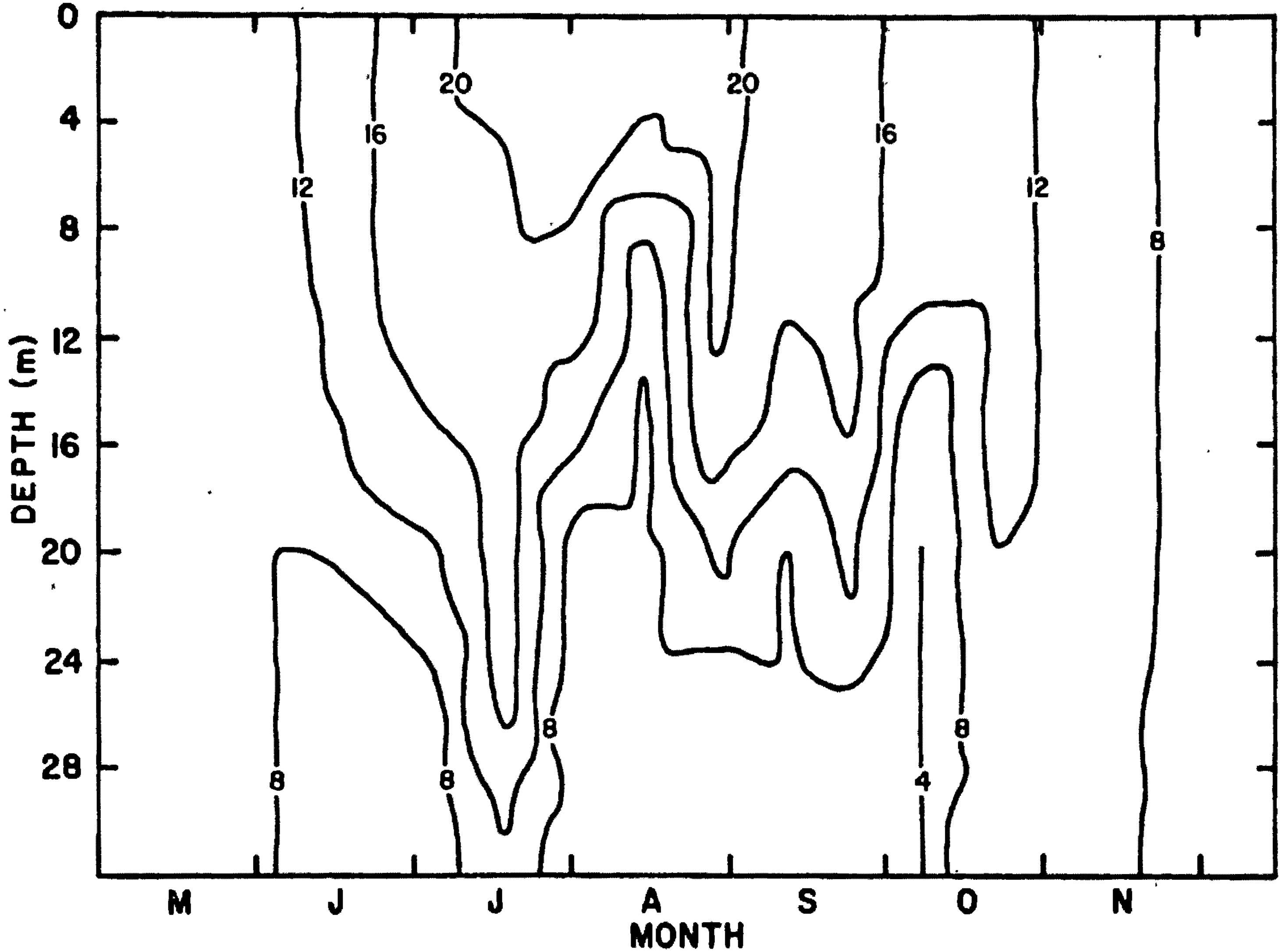

Figure 14 Thermal structure of the nearshore (35m depth), Lake Ontario off Sandy Creek, 1984.

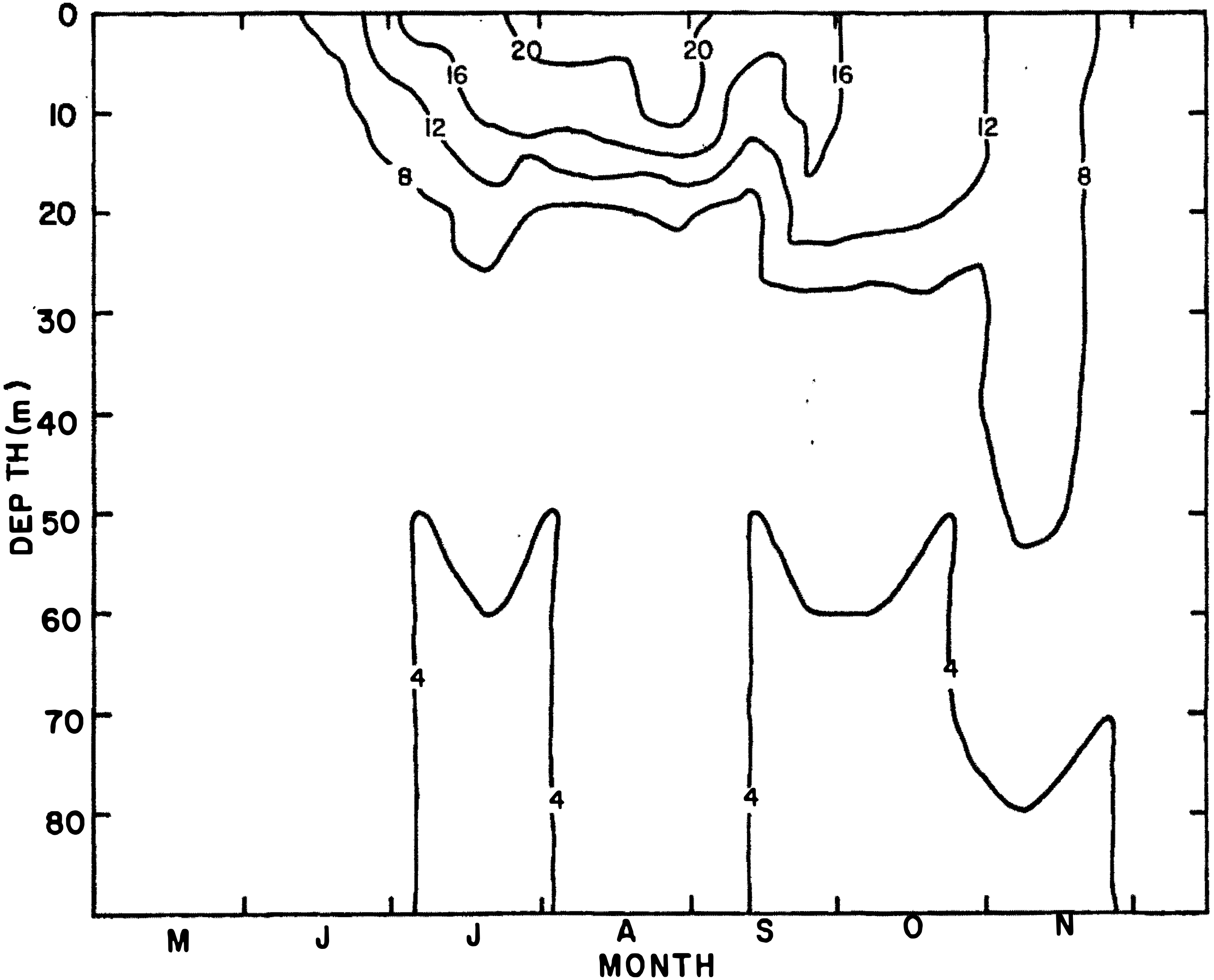

Figure 15 Thermal structure of the offshore (100m depth), Lake Ontario off Sandy Creek, 1984.

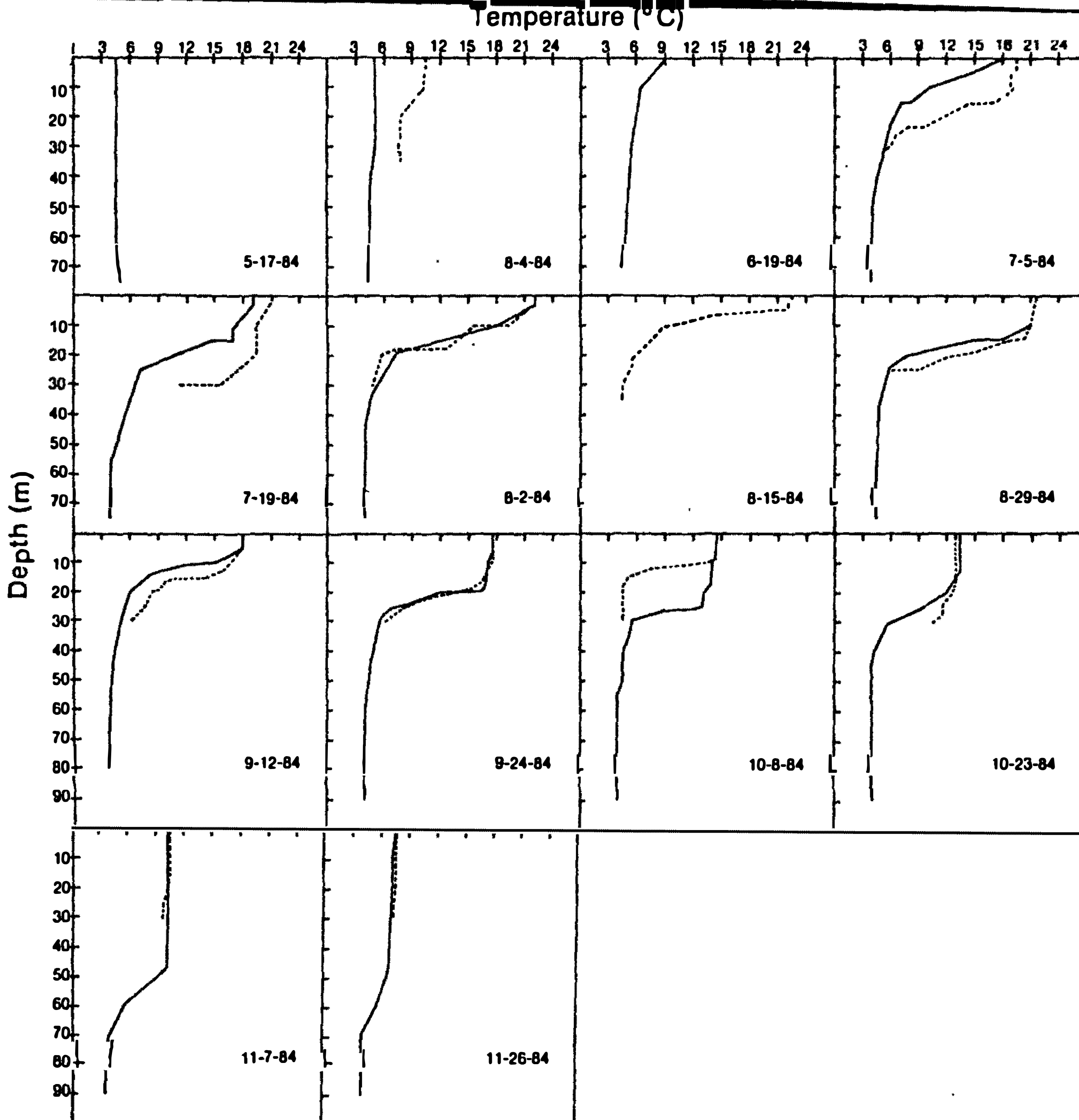

Figure 16 Temperature profiles at the 35m and 100m stations, Lake Ontario off Sandy Creek, 1984.

Table 1 Percentage of total production each cohort contributed to the *Mysis relicta* population at the 35m and 100m stations, Lake Ontario off Sandy Creek, 1984.

	35m station	100m station
Cohort 1	----	1%
Cohort 2	43%	31%
Cohort 3	51%	61%
Cohort 4	6%	7%
Cohort 5	----	<1%
Cohorts 2&3	94%	92%

Table 2. Percent composition of alewife diets, including differing feeding strategies and average composition for the total population, Lake Ontario off Nine Mile Point. (C. Iancu, 1987).

	Feeding Strategy One	Feeding Strategy Two	Mean of both strategies
January	100%	----	
Mysis			9.19%
Pontoporeia			89.31
zooplankton			1.49
other			----
March	100%	----	
Mysis			10.00
Pontoporeia			89.18
zooplankton			0.82
other			----
May	100%	----	
Mysis			7.41
Pontoporeia			90.71
zooplankton			0.33
other			1.41
June	12%	88%	
Mysis	71.36	----	8.56
Pontoporeia	----	----	----
zooplankton	27.93	97.50	89.15
other	0.71	2.50	2.29
August	39.5%	60.5%	
Mysis	45.98	----	30.62
Pontoporeia	33.56	----	7.51
zooplankton	20.37	100.00	61.70
other	0.08	----	0.06
October	66.5%	33.5%	
Mysis	48.54	----	46.12
Pontoporeia	0.12	----	0.11
zooplankton	5.44	100.00	36.28
other	5.63	----	2.14
Gammarus	40.18	----	15.27
November	100%	----	
Mysis			----
Pontoporeia			19.39
zooplankton			80.61
other			----

Table 3. Comparison of the 1971 study by Carpenter (1974) and this study of the Mysis relicta population of Lake Ontario.

	Carpenter	This study
Sampling Year	1971	1984
Lake	Ontario	Ontario
Number of Stations	33	2
Station Depth	0-225m	35 and 100m
Number of Cruises	3	14
Sampling Time	Day and Night (no differences found)	Night
Sampling Gear	Vertical Haul	Vertical Haul
Mesh Size	505um	571um
Mouth Diameter	1.0m	0.5m
Mean Abundance Values	$0.14/m^3$ at 25-50m $1.15/m^3$ at 75-100m $1.67/m^3$ at 100-125m	$1.37/m^3$ at 35m $4.04/m^3$ at 100m
Range of Abundance Values	3.5-$7.0/m^2$ at 25-50m 86-$155/m^2$ at 75-100m 167-$209/m^2$ at 100-125m	$48/m^2$ at 35m $378/m^2$ at 100m

Table 4. Comparison of Mysis relicta studies done on Lakes Michigan, Huron and Ontario.

	Grossnickle & Morgan (1979)	Reynolds & DeGraeve (1972)	Beeton (1960)	Morgan & Beeton (1978)	Johannsson et. al. (1985)	Johannsson et. al. (1985)	This study 35m	This study 100m
Sampling year	1975-1976	1970-1971	1954	1975-1976	1981-1983	1981-1983	1984	1984
Lake	Michigan	Michigan	Michigan	Michigan	Ontario	Ontario	Ontario	Ontario
Station depth (m)	50	45-73	74	115	35	105	35	100
Sampling time	Night	Day	Night	Day	Day	Day	Night	Night
Production	3.2 (dry g/m^2/year)	0.25 (dry g/m^2/year)	2.5 (dry g/m^2/year)	1.7 (dry g/m^2/year)	----	----	0.13 (dry g/m^2/7 mo.)	1.23 (dry g/m^2/7 mo.)
Biomass (dry g/m^2)	1.11	0.11	0.85	0.52	<0.00	0.01	0.08	0.68
Density (#/m^2)	434	25	349	171	4	17	48	378
P:B ratio	2.9 (year)	2.2 (year)	2.9 (year)	3.3 (year)	----	----	1.6 (7 months)	1.8 (7 months)
Sampling gear	Vertical haul	Sled	C-B horizontal	Sled (flowmeter)	Ponar grab sampler	Ponar grab sampler	Vertical haul	Vertical haul
Mesh size of net (um)	570	656	366	570	----	----	571	571

Table 5a. Biomass and abundance values of the major zooplankton groups at the 35m station, Lake Ontario off Sandy Creek, 1984. CAL=Calanoida, CLA=Cladocera, COP=nauplii of copepoda, CYC=Cyclopoida, ROT=Rotifera, MYS=Mysidacea.

GROUP	Total biomass mg/m^3	Percent biomass mg/m^3	Average biomass mg/m^3	Percent abundance $\#/m^3$	Average abundance $\#/m^3$
CAL	68.2	2.1	4.9	0.5	2189.6
CLA	430.7	13.2	30.8	6.8	32447.4
COP	358.9	11.0	25.6	13.5	64086.6
CYC	2113.5	65.0	151.0	12.4	58773.6
ROT	246.7	7.6	17.6	66.9	318258.6
MYS	33.3	1.0	2.4	<0.0	1.4

Table 5b. Biomass and abundance values of the major zooplankton groups at the 100m station, Lake Ontario off Sandy Creek, 1984. CAL=Calanoida, CLA=Cladocera, COP=nauplii of copepoda, CYC=Cyclopoida, ROT=Rotifera, MYS=Mysidacea.

GROUP	Total biomass mg/m^3	Percent biomass mg/m^3	Average biomass mg/m^3	Percent abundance $\#/m^3$	Average abundance $\#/m^3$
CAL	86.4	5.7	6.6	0.9	1585.3
CLA	162.7	10.7	12.5	7.8	13265.7
COP	162.8	10.7	12.5	18.5	31304.1
CYC	977.7	64.1	75.2	17.7	29889.2
ROT	46.2	3.0	3.6	55.1	93219.0
MYS	88.5	5.8	6.8	<0.0	3.8

Table 6. Abundance comparisons of stage one versus stage three embryos found in the *Mysis relicta* population, Lake Ontario off Sandy Creek, 1984. Stage one embryos are in the earliest developmental stage of the embryo with no activity present and the third stage occuring when the embryo is about to undergo its first molt.

Total number of embryos in sample	Stage 1	Stage 3
17 May	----	27
19 June	53	----
8 October	101	----
23 October	80	12
7 November	113	----
26 November	38	35
Total number of gravid females	13	4
Total number of eggs	385	74
Mean number of eggs per female	29.6	18.5